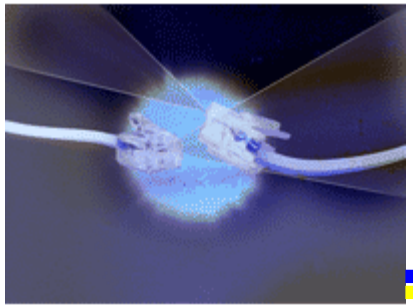
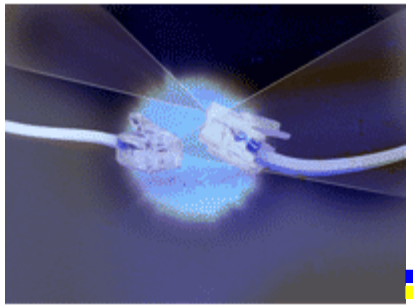


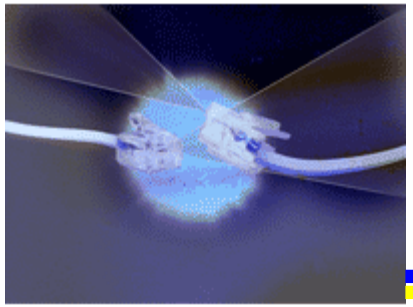
Ethernet (802.3)

- Developed at Xerox Palo Alto Research Center (PARC) in the mid-70s
- Digital Equipment Corporation (DEC) and Intel helped Xerox define the 10 Mbps standard in 1978 – basis for IEEE 802.3 standard
- 802.3 later extended to other physical media, and to include 100 Mbps Fast Ethernet and 1 Gbps Gigabit Ethernet



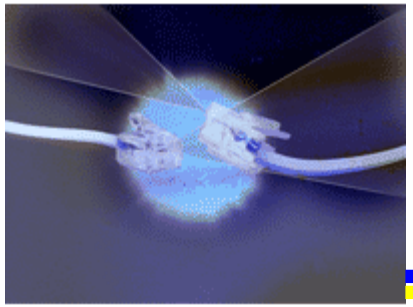
CSMA/CD

- Ethernet based on Carrier Sense Multiple Access with Collision Detect technology
  - Multiple nodes share the link – wire serves as a bus
  - Carrier sense means that every node can distinguish between idle and active link
  - Collision detect means that a node listens as it transmits and can tell if its transmission has "collided" with a transmission by another node



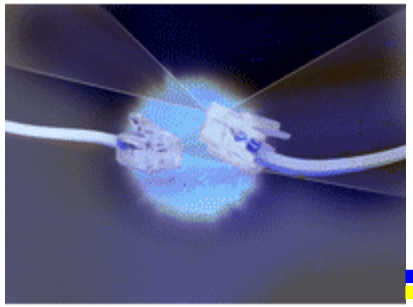
Physical Medium

- Ethernet segment is a length of coaxial cable up to 500 m long
- Impedance is 50 Ω
- Taps are at least 2.5 m apart
- *Transceiver* senses carrier, drives signal onto line, simultaneously receives signal from line



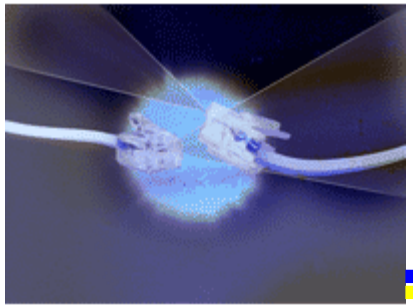
Physical Medium (cont.)

- Transceiver connects to Ethernet *adaptor* that implements control logic
- Multiple segments can be joined by *repeaters*. Repeater regenerates digital signal
  - No more than 4 repeaters between any two hosts, so max separation is 2,500 m
- Segment ends in *terminator* that prevents reflection of signal back up cable

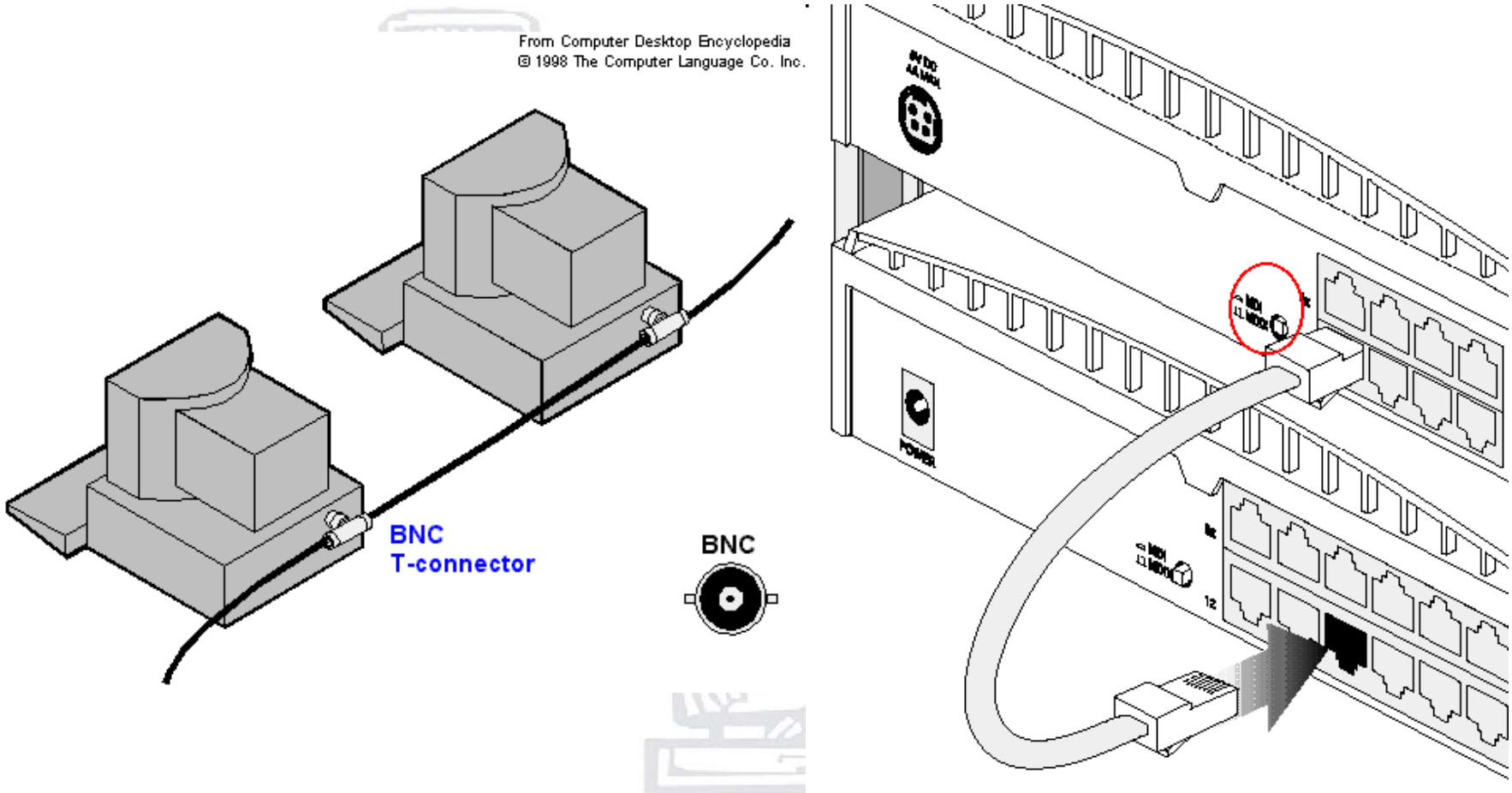


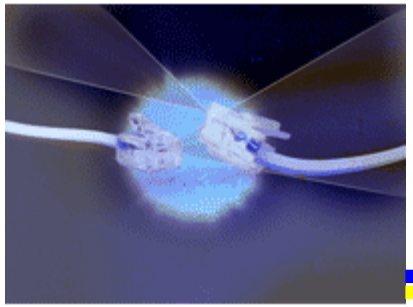
Physical Medium (cont.)

- Maximum of 1,024 hosts
- Manchester encoding used on wire
- Original medium called 10Base5, or *thick-net*. Other media introduced later:
  - 10Base2 (*thin-net*) – 200 m
  - 10BaseT (twisted pair, Cat5) - 100 m 10BaseT cable does not use taps into cable; requires a *hub*
- Regardless of medium and number of segments or hubs, all nodes on network see the wire as a single link



Physical Medium (cont.)



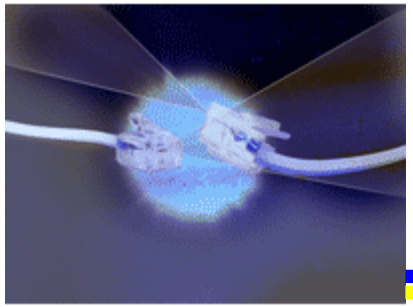


Access Protocol

- MAC (*media access control*) algorithm controls access to link
- Frame format:

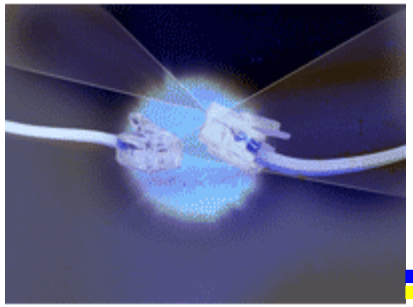
64	48	48	16	368 - 12,000 bits (46 - 1,500 bytes)	32
Preamble	Dest Addr	Src Addr	Type / Length	Body …	CRC

  - Preamble is alternating 0s and 1s; allows receiver to sync on signal
  - Type flag identifies higher level protocol; in 802.3, this is length. Ethernet type values all > 1500, so receiver can handle both protocols



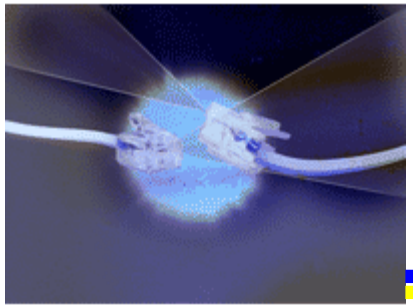
MAC Addresses

- 48-bit MAC address is unique (or supposed to be) for every Ethernet adapter in the world
  - Address blocks allocated to manufacturers
- Address typically displayed as six two-digit hex values; i.e. 00:50:2C:0A:0B:EE
- Special address FF:FF:FF:FF:FF:FF is *broadcast* address
- Any other address with first bit 1 is a *multicast* address



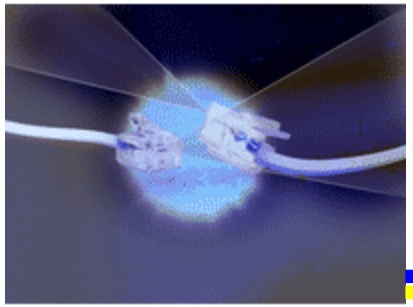
MAC Addresses (cont.)

- Multicast addresses are used to send to some subset of nodes – each adapter must be told which multicast addresses it should recognize
- Some adapters can be placed into *promiscuous* mode, which will receive all frames regardless of address



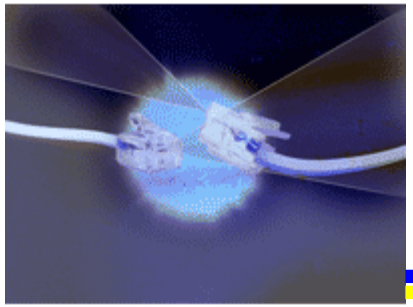
Transmitter Algorithm

- When adapter has data to send and line is idle, it transmits immediately
  - 1500 byte max data size limits time it can occupy link
- When adapter has data to send and line is busy, it waits until line is idle, then transmits immediately
  - Called a *1-persistent* algorithm, since there is a 100% chance it will transmit as soon as line is idle



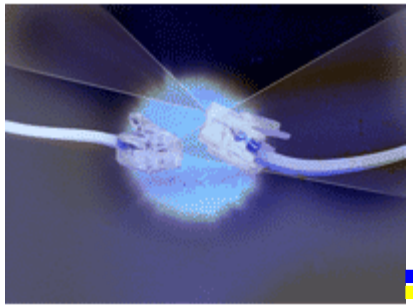
Collisions

- Alternative is *p-persistent* protocol, where $0 < p < 1$
  - This decreases chance that two nodes will transmit at the same time
  - Ethernet just uses 1-persistence
- Collision occurs if two nodes transmit at the same time
  - Any adapter that detects a collision sends a 32-bit jamming sequence and stops sending



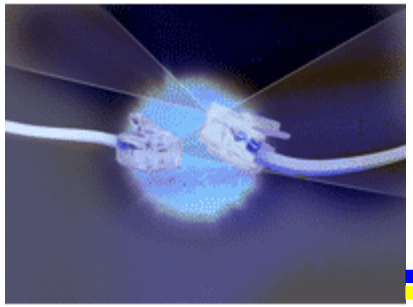
Collisions (cont.)

  - Shortest frame thus 64 bit preamble and 32 bit jamming sequence.
- Longest time it can take for signal from one host to reach another is 512 bits – this is based on bit width, propagation speed of signal in wire and maximum length of network (2500 m)
  - This is why there is a minimum data length for packet; sender must pad shorter messages



Collisions (cont.)

- After sender detects a collision and stops, it waits either 0 or 51.2 μs (chosen randomly), then retransmits if link is idle
- If transmission fails, adapter increases the wait time – multiplies by 51.2 μs by a random number from 0 to 3
- Next failure multiplies by 0 to 7
- *Exponential backoff* – *n*th try multiplies by 0 to 2^n
- Retry up to 16 times, but *n* capped at 10



Empirical Performance

- Because of possibility for collisions, Ethernet works best if not heavily loaded
  - Utilization over 30% is heavy
- Ethernet network is simple, easy to administer, inexpensive